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RESEARCH PAPER NO. 69
DECEMBER 1962

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PRELIMINARY AERIAL VOLUME TABLES FOR PINYON-JUNIPER STANDS

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INTRODUCTION

The increased interest in pinyon-juniper stands as a source of charcoal and other wood utilization products has created a need for reliable volume estimates of this woodland type.

Pinyon-juniper stands have always been important to the Southwest, where it was often the only available source of fuel and fenceposts. Rarely more than 15 to 30 feet in height, this mixture of pinyon pine and one or more species of juniper extends in open stands over an estimated 51 million acres in Arizona, Colorado, Nevada, New Mexico, and Utah. This is roughly 2.5 times the area of commercial forest land. Most of the area occupied by this type is largely incapable of producing sawlog species because it receives so little precipitation, but it is important as a watershed forest and winter range capable of producing some essential wood products.

THE PROBLEM

These short scrubby conifers of small size, rapid taper, and brushy appearance discourage the sawlog forester, and present a real problem in volume estimating to private owner and public forester alike. Pinyon pine and the several junipers are not only poor in quality, but often their rapid taper and multiple stems make the estimating of utilizable wood products extremely difficult. Per acre values are usually so low that conventional ground cruising methods may cost more than the products are worth. What has been lacking is a reliable cruising technique, easily applied and cheap enough to provide estimates in line with the value of the product.

Little is known about either tree or per acre volumes in this woodland type, even though some fuelwood studies (6, 7) of both one-seed and Rocky Mountain junipers were made in the late 1930's. Data from these studies provided tables showing fuelwood volumes in cubic feet by diameter at stump height and maximum crown width, as well as by d.b.h. and total

Figure 1.--This tree at the edge of a pinyon-juniper stand illustrates typical characteristics of the species: relatively small size, rapid taper, and brushy crown.

height. These, of course, were ground volume tables and they could do little to reduce the cost of conventional cruising techniques. Aerial estimating techniques, however, can make the estimation of pinyon-juniper stands practical. These techniques, which combine sampling and precise stand measurements made on aerial photos with the use of adequate volume tables, offer a possible 50- to 75-percent reduction in the cost of timber estimating. They are particularly applicable to estimates of low value stands.

THE TABLES

The development of aerial photo volume tables is the first step towards effective use of aerial estimating techniques. The following two aerial volume tables have recently been compiled at the Intermountain Forest and Range Experiment Station, Ogden, Utah:

1. The cubic-foot volume table.--This table lists per acre volume in cubic feet by average stand height and crown cover percent in four crown diameter classes. The format is that used in previous aerial volume tables published by the Central States and the Intermountain Forest and Range Experiment Stations.

2. The fencepost table.--This table lists number of juniper fenceposts per acre by average stand height and crown cover percent in four crown diameter classes. The same format is used.

ACCURACY

Standard measures of accuracy are shown at the bottom of each table. The standard error of estimate (in percent) for the cubic-foot table is somewhat higher than that for previously published aerial volume tables. In pinyon-juniper stands we are estimating extremely short trees with a narrow range of total height and crown cover, and with very low per acre volumes. Therefore, this ±60 percent represents a low 100 cubic-feet-per-acre error, which is quite satisfactory for most purposes.

The fencepost table is our first attempt to construct an aerial table for estimating products. The high standard error of estimate for this table indicates extreme variability in number of posts per acre largely introduced by some 10 to 15 percent pure pinyon plots. Since present photo interpretation techniques do not enable the interpreter to separate pinyon and juniper on the available small scale aerial photos, this variability must be accepted in constructing a practical table. Additional research, particularly if conducted on large scale aerial photos, will undoubtedly help us to improve this table.

These two tables are preliminary in that they are based on only 48 locations measured in Utah. We hope to test them throughout the Southwest. As more data from Forest Survey field plots become available, the tables can be revised.

HOW TO USE THESE TABLES

To use these aerial volume tables you must be able to measure consistently on aerial photos the three independent variables used in constructing the tables:

1. Average total height of the dominant stand.--This average is based on the five tallest trees within the acre plot, and is recorded to the nearest 5 feet. In practice, this average is obtained from five independent measurements of the tallest trees within the acre plot. Measurements are made by parallax wedge or other parallax measuring device of equal accuracy.

2. Average crown diameter of the dominant stand.--This average is based on the five largest crowns as measured by the crown diameter

scale and is recorded in 5-foot crown diameter classes. In practice, this average is usually obtained from five independent crown measurements of the tallest trees.

3. The percent of crown cover of the dominant stand.--This percentage is obtained by comparison with the crown cover scale, which reads the midpoint of the nearest 10-percent class. In practice, crown coverage of the dominant stand is used only when stands are clearly two-storied. In even-aged stands the crown coverage percent includes crowns of the entire stand.

The table is entered with these three readings. For example: if five measurements of the tallest trees on the acre plot result in an average total height of 20 feet, and if five crown diameter readings of these or comparable trees result in an average crown diameter between 13 and 17 feet, and if 25 percent of the acre is covered by crowns of this stand, then we can expect the cubic volume to average 330 cubic feet per acre, and on the average we can expect to have thirty-nine 7-foot posts per acre.

HOW THE TABLES WERE CONSTRUCTED

The basic data for this study were obtained from 48 field locations measured by Forest Survey field crews during the summer of 1961. The locations comprised a random sample selected from the 2,000 to 3,000 photo points, within the State of Utah, previously classified as pinyon-juniper type. The center of each selected location was pinpricked on aerial photos. Using these photos, field crews located each sample point on the ground and measured a total of five 1/50-acre circular plots in a diamond-shaped pattern (fig. 2) within the circular 1-acre location. Independent measurements of these same 1-acre locations were then made on the aerial photos. Finally, the relations between measurements of total height, crown diameter, and crown coverage, and the cubic-foot volume and number of fenceposts per acre were studied and the table compiled.

Field measurements.--Five 1/50-acre circular plots (a total of 1/10-acre) were measured at each selected location. All live trees and clumps with stems 5 inches d.b.h. and larger, and with a minimum length of 4 feet to a 4-inch top diameter were measured for cubic volume. Measurements consisted of butt diameter (12 inches above ground), length to the nearest 1 foot, top diameter to a minimum of 4 inches d.o.b. and bark thickness. Gross cubic volume was computed by Smalien's formula.

The number of fenceposts was tallied on all live juniper trees and suitable stems in clumps. Minimum requirements were a 7-foot length

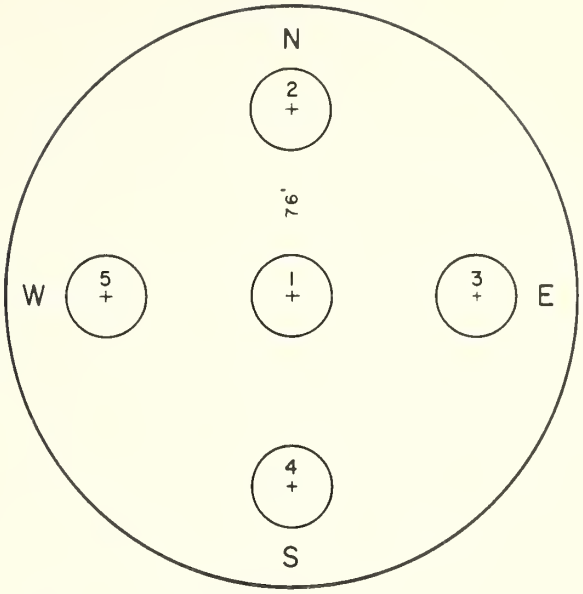

Figure 2.--Distribution of a 5-plot grid on a circular 1-acre area. Each of the five plots is 1/50 acre; hence each grid provides a total measurement of 1/10 acre at each location.

with a maximum butt diameter of 7 inches and a minimum top diameter of 3 inches. Ten-foot lengths were tallied as 1-1/2 posts. In addition, total heights and crown diameters were tallied on a minimum of one dominant tree in each species (pinyon or juniper) found on each 1/50-acre subplot. The resulting measurements, a minimum of five per location, were used to obtain average total height and crown diameter.

Photo measurements.--Aerial photos on which plots were pinpricked and measured were nominal 1:20,000-scale USDA panchromatic prints. Precise measurements were made, independent of the field data, for all commonly used aerial volume variables. These are:

Average total height of the dominants: Obtained from the five tallest trees at each location, as measured by parallax wedge.

Average crown diameter of the dominants: Obtained from the five largest crowns at each location as measured by the dot-type crown diameter scale.

Crown cover percent: Obtained by comparison with the printed crown cover scales, and checked by the average of three dot counts per location, made with a 28-dot-per-acre microdot shield.

PRELIMINARY AERIAL VOLUME TABLE--PINYON-JUNIPER TYPE

Gross cubic volume per acre by average stand height, average crown diameter, and crown coverage[1/]

Average stand height (feet)	Crown cover (percent) 5	15	25	35	45	55	65	75	85	95
	Ten cubic feet									
4- TO 7- (5) FOOT CROWN DIAMETER										
10	2	2	2	1	1	0				
15	2	5	7	10	11	13	15	17	19	21
20						14	18	22	26	30
8- TO 12- (10) FOOT CROWN DIAMETER										
10	2	2	2	2	2	2	2	2	1	1
15	12	15	17	20	22	25	27	29	31	33
20	12	16	21	26	31	35	40	44	49	53
25							41	48	54	61
13- TO 17- (15) FOOT CROWN DIAMETER										
15	13	16	19	21	24	26	29	32	34	36
20	22	28	33	38	43	48	52	57	62	67
25		28	35	42	49	56	64	71	78	85
30								73	82	91
18- TO 22- (20) FOOT CROWN DIAMETER										
15	5	8	11	14	17	19	22	25	27	30
20	24	30	35	40	45	51	56	61	66	71
25	32	39	47	55	62	70	77	85	92	99
30			47	57	67	77	87	97	107	116
35								97	109	121

1/ Figures in blocked out areas are based on field data.

Note: Average stand heights and crown diameters were obtained from field measurements, and crown cover was obtained from photo measurements of field plots. Cubic volume was computed from field measurements.

Based on 48 Forest Survey field plots randomly located in Utah.

Aggregate deviation: Table -0.17 percent low.
Standard error of estimate: ±60 percent of mean plot volume.

PRELIMINARY AERIAL VOLUME TABLE--PINYON-JUNIPER TYPE

Number of 7-foot juniper fenceposts per acre by average stand height, average crown diameter, and crown coverage[1]

Average stand height (feet)	Crown cover (percent) 5	15	25	35	45	55	65	75	85	95
	Number of posts									
4- TO 7- (5) FOOT CROWN DIAMETER										
10	4	7	9	9	6	2				
15			17	29	39	46	52	56	57	57
20				35	57	77	95	111	125	136
25					61	94	124	153	179	203
30						97	139	180	219	255
8- TO 12- (10) FOOT CROWN DIAMETER										
10	7	7	6	2	2					
15		13	24	33	39	43	46	46	44	41
20			28	49	68	85	99	112	122	130
25			18	52	83	112	139	164	186	207
30				40	84	125	164	201	237	270
13- TO 17- (15) FOOT CROWN DIAMETER										
10	4	1								
15	8	17	24	30	33	34	33	30	24	17
20		19	39	56	72	85	96	106	113	118
25		8	40	69	97	123	146	168	187	205
30					108	146	182	216	248	277
18- TO 22- (20) FOOT CROWN DIAMETER										
10										
15	8	14	18	20	20	17	13	6		
20	9	27	43	57	69	79	87	93	97	98
25		25	54	80	105	127	147	165	181	196
30				90	126	161	193	224	252	279

1/ Figures in blocked out areas are based on field data.

Note: Average stand heights and crown diameters were obtained from field measurements, and crown cover was obtained from photo measurements of field plots. Number of fenceposts was computed from field tallies.

Based on 48 Forest Survey field plots randomly located in Utah.

Aggregate deviation: Table 3.1 percent high.
Standard error of estimate: ±117 percent of mean plot volume.

EVALUATION OF FIELD AND PHOTO DATA

Studies have been made to determine the most useful variables in the construction of aerial volume tables; but the conclusions vary with studies and do not consider pinyon-juniper. Most studies find average total height and crown cover significantly related to volume (1, 2, 3, 4, 11), but at least one recommends average total height alone and another crown cover alone (12) while a third bases an entire set of aerial tables on crown diameter alone (5).

Reliable measurements of total height and crown diameter can be made on the aerial photos (9) or on the ground, but past studies disagree as to which technique is better. Crown cover is difficult to determine on the ground, but is easily estimated on aerial photos either by crown cover scale or by dot count (2); the latter system is much slower. Because the conclusions of previous studies did not agree, we decided to use all three variables. We were interested in the accuracy of photo measurements in pinyon-juniper; so we compared the photo measurements of total height and crown diameter with those obtained in the field. These data from the 48 locations studied are summarized:

Average height and average crown diameter obtained from photo and field measurements

Measurement	Average all plots		Mean aggregate error	Std. error of estimate	Coefficient of correlation
	Photo	Field			
	- - -Feet- - -		Feet	Feet	
Av. ht. of dominant stand (five trees)	15.6	15.0	+0.6	±2.5	0.819*
Av. cr. dia. of dominant stand (five trees)	12.7	12.8	−.1	±3.2	.632*

* Significant at 95-percent level.

We also compared estimates of crown cover percent made by printed scale and by microdot:

By microdot count	29.1
By crown cover scale	26.5
Mean aggregate error	-2.6
Standard error of estimate	±4.4
Coefficient of correlation	0.917*

* Significant at 95-percent level.

These comparisons indicate that the five-tree averages for total height and crown diameter can be obtained from either photo or field measurements with about the same accuracy, and that crown cover can be estimated by comparison with crown cover scale about as well as by dot count.

Although field and photo measurements did not appear to be significantly different, we assumed the field measurements of average height and crown diameter would have less chance of bias. Since the crown cover scale used on aerial photos is the most efficient means of measuring crown cover, we used these readings instead of dot counts. We then computed correlations and tested the three variables for their usefulness in the tables. The following tabulation lists some of the single as well as the multiple curvilinear correlations between these variables and cubic volume and number of fenceposts.

Correlations of stand variables with cubic volume and number of fenceposts

Stand variable	Cubic volume	Number of fenceposts
H (Average height five dominant trees)	0.7256**	0.3418*
CD (Average crown diameter five dominant trees)	.4519**	.0674
CC% (Crown cover percent total stand)	.3722**	.3960**
H, H^2 (Curvilinear)	.7797**	.5339**
H, CC%	.7791**	.5710**
H, H^2, CD, CD^2, CC%, $CC\%^2$ (Curvilinear)	.8031**	.5800**

* Significant at 95-percent level.
** Significant at 99-percent level.

In the case of cubic volume, the best single correlation (0.7256) was obtained with average total height. Both crown diameter and crown cover were also correlated, but this may have been partly due to interaction between these independent variables. The curvilinear relationship using all three variables and their squares produced the highest multiple correlation (0.8031). Even though this addition was not necessarily significant, it agreed with previous studies (8, 10) that had indicated some advantages might be realized by using the three variables.

In the case of number of posts, correlations were much lower, with crown cover the best (0.3960), and height next (0.3418). Multiple correlation using all factors again proved just slightly higher (0.5810).

In machine compilation of the table, the six-term multiple regression was used because at this time our knowledge of pinyon-juniper does not justify dropping any practical aerial photo variable.

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